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A Long-Term Variation of the Cosmic Ray Flux in the Solar Cycle 24 and 25

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Abstract: *In this paper, we study long term variation of cosmic ray fluxes during solar cycles 24 and 25. We also report that solar cycle 25 will have slightly higher fluxes than 24, but overall it is still considered a weak cycle. This means that the cosmic ray flux will be relatively high during the minimum phases of each cycle due to low solar modulation. But the overall trend is that the flux will be lower than in previous, more active cycles. This research observed a major increase in cosmic ray flux during the transition between solar cycles 24 and 25. The minimum period between cycles saw significantly higher levels of galactic cosmic rays than the previous solar minimum. Where the Sun's overall activity is particularly low; this means that during the transition from cycle 24 to 25, the Earth experienced a higher flux of cosmic rays due to the reduced solar shielding effect. Our recent period of Solar Cycle 25 has reached a higher number of sunspots than Solar Cycle 24, which peaked in 2014. We would anticipate more flares with higher sunspot counts. When a higher level of solar activity during a cycle results in a lower cosmic ray flux due to the increased solar modulation effect, the available data indicates that the cosmic ray flux peak value generally decreased from Solar Cycle 20 to 24. Solar Cycle 21 showed the highest peak value, followed by Cycle 22, then 23 and finally the lowest peak in Cycle 24 but the solar cycle 25 maximum on July 2025. This research we are analyzing of solar cycle 24 and 25 with cosmic ray activities detection methods*

Keywords: Cosmic Ray Flux, Solar Cycle, Sunspot, Cosmic Ray, Solar Wind, IMF, GCR

I. INTRODUCTION

The term "cosmic ray flux 24 & 25" refers to the flux of cosmic rays measured during Solar Cycles 24 and 25. Within each cycle, flux decreases during periods of high solar activity (solar maximum) and increases during low activity periods (solar minimum). A notable shift in flux occurs during the transition from Cycle 24 to Cycle 25, a phenomenon often studied by researchers analyzing cosmic ray variations over time. The main factor affecting cosmic ray flux is solar activity, which regulates the flux of galactic cosmic rays reaching Earth through mechanisms such as the solar wind and the heliospheric magnetic field. Researchers often examine the transition between Solar Cycles 24 and 25 to analyze changes in cosmic ray flux as solar activity moves from the minimum of Cycle 24 to the rising phase of Cycle 25. The flux of cosmic rays entering the higher atmosphere varies based on the solar wind, Earth's magnetic field and the energy of the cosmic rays. Around ≈94 AU from the Sun, the solar wind slows from supersonic to subsonic speeds at a boundary known as the termination shock. The region between this boundary and the heliopause serves as a barrier, reducing the flux of lower-energy cosmic rays (≤1 GeV) by approximately 90%. However, because the solar wind's flux fluctuates, cosmic ray flux has been observed to correlate with solar activity. Additionally, Earth's magnetic field deflects cosmic rays, causing the observed flux to vary with latitude, longitude, and azimuth angle. The combined influence of these factors determines the flux of cosmic rays at Earth's surface. The following table shows the frequencies of incoming particles, inferred from lower-energy radiation detected at ground level.

Relative energies and flux rates of cosmic rays

S.N.	Particle Energy (eV)	Particles rate (M^{-2} S^{-1})
1	1×10^{9} (GeV)	1×10^{4}
2	1×10^{12} (TeV)	1
3	1×10^{16} (10 PeV)	1×10^{-7} (a few times a year)
4	1×10^{20} (100 GeV)	1×10^{-15} (ones a century)

Previously, CRF (cosmic ray flux) was thought to remain relatively constant over time. However, recent research indicates that it has undergone one-and-a-half- to two-fold variations on a millennium timescale over the past forty thousand years.

II. DETECTION METHOD

Experiments currently studying high-energy cosmic rays are primarily ground-based. While direct detection tends to be more accurate than indirect detection, the flux of cosmic rays decreases as energy increases, making direct detection less effective for energies above 1 PeV. Both direct and indirect detection methods are implemented using a variety of techniques. Direct detection can be achieved using various particle detectors aboard the ISS, satellites, or high-altitude balloons. However, the weight and size limitations of these platforms restrict the types of detectors that can be used. Several ground-based methods are currently used to detect cosmic rays, which can be categorized into two main types: detecting secondary particles from extensive air showers (EAS) using various particle detectors, and detecting the electromagnetic radiation emitted by EAS in the atmosphere. This figure is use by VERITAS (Date-15 October 2009) and the source of http://www.nsf.gov/news/news_images.jspcntn_id=115836&org=NSF.

The VERITAS Array of Air Cherenkov Telescopes.

III. OBSERVATION

It is clear that space weather conditions are directly related to solar radiation. Geomagnetic activity increases and decreases with the solar-driven movement. In this research paper, we have taken data from the Oulu Neutron Monitor (https://cosmicrays.oulu.fi/) and from Silseo (https://www.sidc.be/SILSO/datafiles). In this research paper, we found that when sunspots decrease, cosmic ray flux increases. We have the taken the data is the Solar Cycle 24 and Solar Cycle 25.

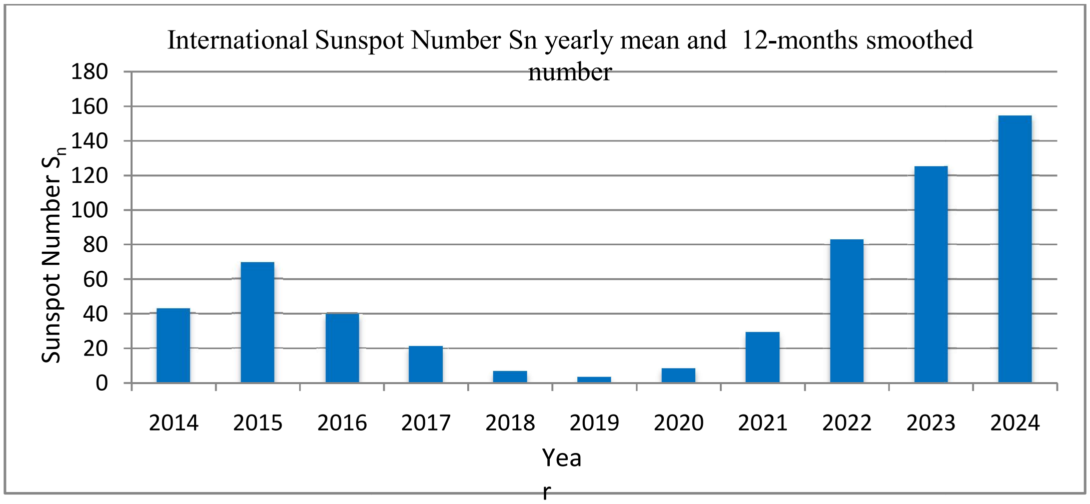

Figure: 1 the number of sunspot each year during 2014-2024

According to Figure 1, we have taken the data of the variation of sunspots for 11 years and in Figure 1 we have shown the data of each year (2014-2024). According to the graph, initially the sunspots remain minimum but later they increase. The data is taken by WDC-Silso (https://www.sidc.be/SILSO/datafiles) station data center. Multi-year figure of the month to month sunspot number and the month to month F10.7. Expected values are based on the agreement of the Sun based Cycle 24 Forecast Board.

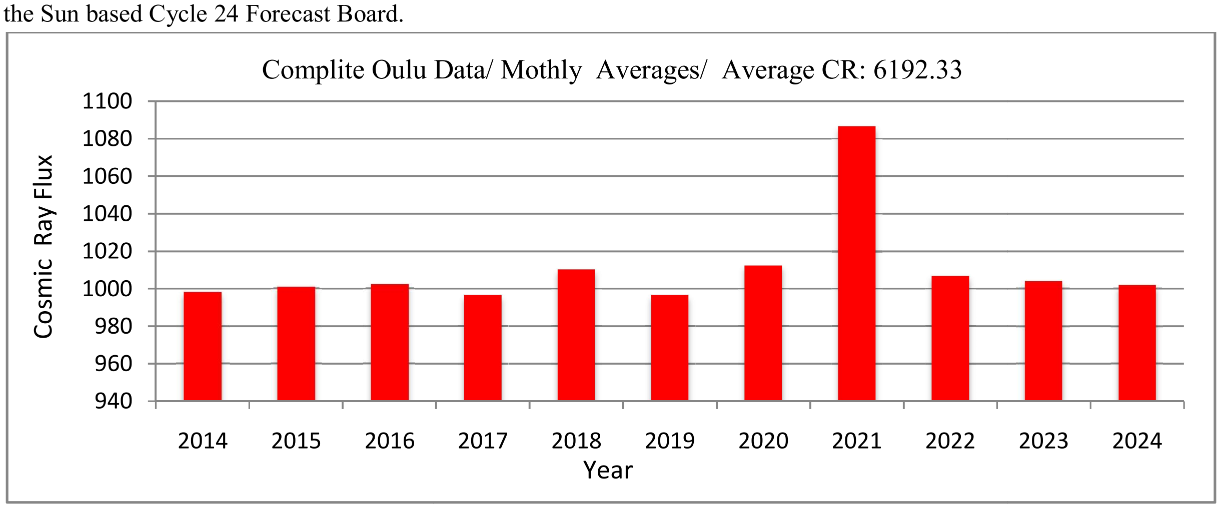

Figure: 2 the number of cosmic ray flux each year during 2014-2024

As per Figure 2, we have taken the data of change of cosmic ray flux for 11 years and in Figure 2 we have shown the data of each year (2014-2024). According to the graph, initially the cosmic ray flux remains low but in 2021 they increase. Then in 2022 they start decreasing, the data of this is taken from Oulu neutron monitor (https://cosmicrays.oulu.fi/).

IV. RESULT

In this research paper, when we do co-correlation between sunspots and cosmic ray flux, we found that when sunspots increase, cosmic ray flux decreases and when cosmic ray flux increases, sunspots decrease. The "active-day" series and the original V1.0 series, with an increasing trend from the 18th to the 20th centuries that does not match the sunspot number series. The plot shows the Oulu NM pressure corrected count rate for the required period. The plot is scaled as (percentage-100%), where 100% is the average cosmic ray flux level for the interval. Figure 3 shows a digital text data output.

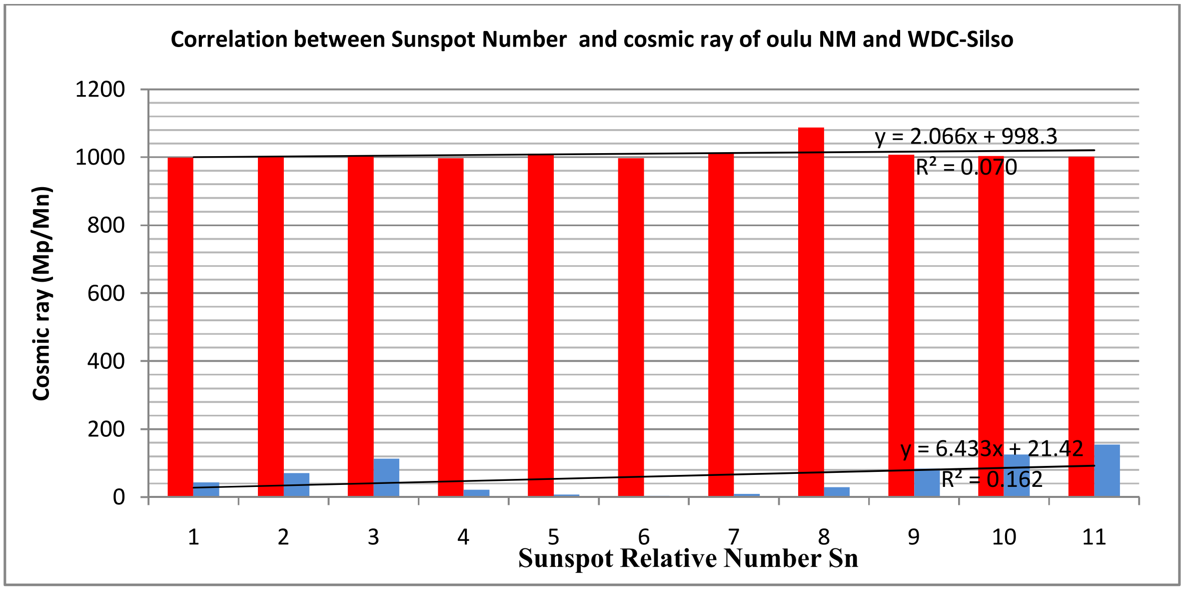

Figure: 3 Correlation between sunspot numbers and cosmic ray flux at Earth's surface from

The cosmic ray flux at the Earth's surface decreased on average during maximum sunspot activity and increased during minimum sunspot activity (Figure 3). The result of linear correlation analysis indicated that the coefficient of correlation between the relative sunspot number and cosmic ray data was -0.4 to -0.5 and the cosmic ray data pressure was 6192.33. The cosmic ray R^2 value of R^2=0.0705 and Sunspot Number R^2= 0.1626 that the input value.

V. CONCLUSION AND FUTURE WORK

In the study, we have taken the data of cosmic ray flux Oulu neutron monitor and sunspot number WDC-SILSO. In this, we found that when cosmic rays worsen, the sunspot number decreases and when sunspots increase, the cosmic rays decrease. Solar Cycle 21 showed the highest peak value, followed by Cycle 22, then 23 and finally the lowest peak in Cycle 24 but the solar cycle 25 maximum on July 2025. The region between this boundary and the heliopause serves as a barrier, reducing the flux of lower-energy cosmic rays (≤1 GeV) by approximately 90%. Research covering the period from 2014 to 2024 indicates a typically negative correlation between cosmic ray flux and sunspot numbers, with a correlation coefficient ranging from approximately -0.4 to -0.5. This suggests an inverse relationship, where an increase in sunspot numbers corresponds to a decrease in cosmic ray flux. It was also observed that cosmic rays can be affected by other solar activities. In the view of this learning that holds different kinds of various appearances of solar radiation particles by the association of some efficient solar activity observations. So, we recommend it is not satisfactory and entire the learning, they will discuss again with some additional interactive appearance in future or after that our research studies

REFERENCES

[1]. Balabin, Y.V., Belov, A.V., Gushchina, R.T. et al. Variations in the Cosmic Ray Flux at the End of Solar Cycle 24. Bull. Russ. Acad. Sci. Phys. 85, 230–233 (2021)
[2]. Forbush, S.E., J. Geophys. Res., 1954, vol. 59, p. 525.
[3]. Dorman, L.I. and Gushchina, R.T., Proc. 15th Int. Cosmic Ray Conf., Plovdiv, 1977, vol. 3, p. 263.
[4]. Vidya Sagar Chaudhary, Sri Krishna Singh, Sarver Ahmad Khan, Bhanu Pratap Singh,C M Tiwari, G N Singh, AK Saxena: Journal Of The Asiatic Society Of Mumbai, ISSN: 0972-0766, Vol. XCVI, No.21, 2023
[5]. Qureshi, Shehrzad (2003), "Cross-Correlation and Matched Filters", Dr. Dobb's Journal, Edition of April 2003, page: 52-56.
[6]. Forbush, S. E. (1957). Large increase of cosmic-ray intensity following solar flare on February 23, 1956. Journal of Geophysical Research, 62 (1), 169-170.

[7]. Iskra, K., Siluszyk, M., Alania, M., and Wozniak, W. (2019). Experimental investigation of the delay time in galactic cosmic ray flux in different epochs of solar magnetic cycles: 1959–2014. Sol. Phys. 294, 115.

[8]. Rani Ghuratia1* , Achyut Pandey2 , Arvind Dhurve3 (2024) A Comparative Approach of Cosmic Ray Variations Within Solar Minimum of Cycle 24. International Journal of Innovative Research & Growth DOI: 10.26671/IJIRG.2024.3.13.109.

[9]. Dembinski, H.; et al. (2018), "Data-driven model of the cosmic-ray flux and mass composition from 10 GeV to 10^11 GeV", Proceedings of Science. ICRC2017: 533.

[10]. Dorman, L. I., and L. A. Pustil'nik (2005), On the probability of solar cosmic ray fluency during SEP event in dependence of the level of solar activity, Conf. Paper Int. Cosmic Ray Conf. XXIX, 2, 331– 334.

[11]. Jitendra Satnami, Achyut Pandey (2022) Cosmic ray intensity variation in relation with sunspot numbers and geomagnetic activity parameter Kp and Ap index during the period of 1997-2007, ISSN: 2455-1848, Volume: 11 Issue: 4.

[12]. Agrawal R., Mishra, R.K., (2007). Solar cycle phenomena in cosmic ray intensity up to the recent solar cycle. Physics Letters B, 664, 31-34.

[13]. Mavromichalaki, H., Petropoulos (1984). Time-lag of cosmic-ray intensity, Astrophysics and Space Science, 106, 61–71.